EVALUATION OF ACCURACY AND RELIABILITY OF THREE DIFFERENT COMPUTERIZED CEPHALOMETRIC PROGRAMS NEMOCEPH, ONYX AND FACAD WITH CONVENTIONAL HAND TRACING METHOD

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CERTIFICATE

This is to certify that this dissertation titled "EVALUATION OF ACCURACY AND RELIABILITY OF THREE DIFFERENT COMPUTERIZED CEPHALOMETRIC PROGRAMS NEMOCEPH, ONYX AND FACAD WITH CONVENTIONAL HAND TRACING METHOD" is a bonafide record of work done by **Dr. Aneesh Alim** under my guidance during his postgraduate study period between 2010–2013.

This dissertation is submitted to THE TAMIL NADU Dr. M.G.R. MEDICAL UNIVERSITY, in partial fulfillment for the degree of **Master of Dental Surgery** in Branch V –Orthodontics and Dentofacial Orthopedics.

It has not been submitted (partially or fully) for the award of any other degree or diploma.

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Abstract

The introduction of computerized cephalometric analytic program in treatment planning, is not only expected to decrease the incidence of individual error but also provide standardized, fast and accurate evaluation with high rate of reproducibility. **Aims & Objectives :** The aims and objective of the study are: 1) To compare the accuracy and reliability of three different computerized cephalometric programs Nemoceph, Onyx and Facad with conventional hand tracing method. 2) To evaluate the inter examiner error. **Materials & Methods :** The study was conducted on pre-treatment lateral cephalograms of 20 patients. A total of 9 angular and 5 linear parameters were considered in the study. The manual tracing was considered as control group and was compared with three computerized cephalomatric analytic program. **Results :** No statistically significant difference was found between manual tracing and the computerized tracing programs. The measurements obtained with the cephalometric analysis programs used in the study were reliable. When comparing the accuracy and reliability angular and linear measurements with the three different computerized softwares NemoCeph gave the most accurate and reliable results, which was followed by Facad and Onyx.

Keywords : Computerized Cephalometry, Conventional Hand tracing, Facad, Nemoceph, Onyx Ceph.

Aims & Objectives

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1) To compare the accuracy and reliability of three different computerized cephalometric programs Nemoceph, Onyx and Facad with conventional manual tracing method.

2) To evaluate the inter examiner error.

Introduction

The very essence of clinical orthodontics is the supervision, guidance and correction of the growing dento-facial structures[2,4,9]. With serial cephalometric radiographs, it is possible to study and predict the growth. It is also helpful in evaluating the changes between the pre-treatment and post treatment measurements. Cephalometric analysis can also be used to predict the surgical outcome which is important in treating dentofacial deformities[1,12]. For effecting the same, an accurate treatment plan is mandatory.

Cephalometric radiographs is considered to be an essential tool in the process of diagnosis, treatment plan and for the monitoring of the treatment process[1].

Traditionally cephalometric analysis has been performed manually. This involves the placement of an acetate sheet over the radiograph recording the linear and angular measurement using a ruler and protractor.

Despite of its wide used in the field of orthodontics this technique is time consuming, has disadvantage of being subject errors and systemic errors[2,4,6,10].

The most important source of error includes the variation in landmarks identification, errors in measurements, magnification errors[4,10,13], reduction of three dimensional object to two dimensional object[10].

In computer assisted cephalometric analysis the angles and the distance are automatically calculated, which can eliminate errors in drawing lines between landmarks and is measured with a protractor[7].

The digital image can also be altered and the image can be processed and the visual appearance can be enhanced which can help in the identification of the landmarks[7]. The computer assisted cephalometric analysis decreases the need for data acquisition and for analysis[7].

With the rapid evolution of computer radiography the conventional hand tracing has been slowly replaced by digital tracing. The computerized digital analysis is attaining more popularity and it offers several advantages over the conventional hand tracing. The computerized digital analysis software is easy to use, measurements can be performed quickly, multiple analysis can be performed at the same time, less time consuming, the images are easy to stored as it is in the digital format and it takes up less storage space[9].

It also helps in the superimposition of images[17] and provide the option for altering the size and contrast of the image and provides the ability to archive and improve access to images to overcome the problem of film deterioration.

Moreover patients benefits form decreased dose of radiation exposure and elimination of chemicals and associated environmental hazards.

There are also several drawbacks present . Here it represents the two dimensional representation of a three dimensional structure, so there will be difficulty in identifying the landmarks. There will be superimposition of the bilateral structures, the resolution of the image will be affected as the image is compressed[36]. This computerized cephalometric analysis also requires digital cephalometric radiographic machine as well as its software which is expensive.

Sandler et al[10] and Sayinsu et al[37] have compared the angular and linear measurements, mostly because the reproducibility of lines and angles in more challenging in relation to multiple sources of error than landmark studies[27,34,35]. However the results obtained by the comparison of digitizing method with conventional methods are contradictory.

The aim of this present study is to compare the accuracy and reliability of three different computerize cephalometric programs Nemoceph, Onyx and Facad with conventional hand tracing method, as well as to evaluating intra and interobserver variations.

Review Of Literature

Thomas J.Cangialosi et al[11] evaluated the reliability of computerized prediction program Quick Ceph II[11] of 30 patients pretreatment and post treatment cephalograms of patients who were treated during their active growth period . He found that the variables were virtually same for both the methods. The manual method of prediction gave a good graphical representation of the growth changes . However the computer prediction program offers the added advantages of quicker access to information and greater accuracy in procducing the tracing.

D.B.Forsyth et al[18] stated that the digital imaging have lots of advantages over the conventional cephalometry . The advantages include ease of storage , transmission and enhancement of images. It also reduces the exposure of radiation to the patients .

Darwood[11] suggested that due to improved image quality[18] and other advantages[18] of digital radiography, the conventional radiographs will become obsolete and will be replaced by digital images.

D.B.Forsyth et al[19] compared the image quality of the convetional radiographs with the digital image. He also found out that the random errors associated with angular and linear measurement analyzed on the digital image was greater than the conventional one. So he suggested that in case of digital imaging a pixel matrix larger than 512 X 512 with more than 64 gray levels[19] is required for obtaining a diagnostic quality of the original radiograph.

D.J.Rudolph et al[20] used spatial spectroscopy[20] for automatic computer identification of cephalometric landmarks. The result showed that there is no statistical difference in mean landmark identification error between manual identification and automatic identification using spatial spectroscopy.

Jia-Kuang liu et al[22] showed that computerized cephalometric software can be used for identification of landmarks and for determination of angular measurement. From his study he suggested that the error between manual and computerized identification of landmarks were not significantly different for 5 of 13 landmarks : sella, nasion, porion, orbitlale and gnathion.

Yi Jane Chen[23] et al assessed landmark identification on digital images in comparison with those from original radiograph. Ten radiographs where selected randomly and 19 landmarks where identified on both conventional and digital images. The placement differences for 19 landmarks between two methods were calculated and the vertical and horizontal directions were analyzed respectively. It was identified that the difference of landmark identification of the digital radiograph and the conventional radiograph were statistically significant. Statistically significant differences of inter-observer errors between two modalities were only found for 4 of the 19 land marks.

Yoshihide et al[24] developed a 3D cephalometric system that corrected not only for magnification of the image, but also 3D cephalic malpositioning during cephalogram exposure. Study was conducted and the accuracy unaffected by the cephalic revolution in any direction and standard errors was within 0.8mm in any orthodontic landmark. So it was suggested that this measure system would have sufficient accuracy for clinical application.

P.J.Turner[25] evaluated the reproducibility of land mark identification using scanned cephalometric images in which cephalometric images where scanned and these images where displayed on the monitor for point identification and for subsequent analysis using software. The reproducibility of the points where compared with commonly used methods. It was found that Screenceph is sufficiently accurate to use in a clinical setting but it is not sufficiently exact for use in research projects.

According to the study done by A.Kamoen et al[26] for determining the errors in cephalometric landmark identification it was observed that there were no significant difference in the variances of the co-ordinates for each landmarks between the positions on the digitizer. The ANOVA showed no significant difference in digitation & Levenes test for homogeneity of variance showed significant difference in the co-ordinates of the different landmarks and between the same landmark on different cephalograms.

Yi-Jane Chen et al[29] assessed the concordance between cephalometric measurement derived from landmark identified on digitized cephalograms in comparison with those from original radiographs. It was found that the differences of all cephalometric measurement between original radiographs and their digitized counter parts were statistically significant but clinically acceptable. The interobserver errors for cephalometric measurement on our digitized cephalomteric images are generally comparable with those on the original radiographs.

Ssu-Kuang Chen et al [30] calculated the time required by a clinician to perform the analysis in a conventional manner and also estimated the time using a computerized assisted digital cephalometric analysis system, and the accuracy of the system was also checked. In conclusion it was found that the computerized assisted digital cephalometric analysis system reduces the time needed for cephalometric analysis. It can also help to reduce the human error which occurs during the manual measuring produced in the traditional cephalometric analysis.

Lance Q Bruntz et al[31] evaluated the distortion associated with scanning lateral cephalogram and printing to hard copy and assessed the accuracy of digital images. His study showed distortion between the original and the scanned images showed 0.8 mm vertical enlargement and 0.4 mm horizontal reduction. The printed radiographs showed had 1.1 mm vertical and 0.4 mm horizontal enlargement. All difference were statistically significant.

Although some distortion was found the relative small horizontal and vertical discrepancies were deemed clinically insignificant[31].

Korkmaz et al[36] evaluated the errors in analysis using hand tracing with computerized method. The lateral cephalogram was traced manually by two operators and it was also processed by the same two operators using Dolphin imaging software. The result was each operator consistent in repeated measurements. The angles, maxillary height, maxillary depth, y-axis, FMA, nasolabial angle and distance N perpendicular to point A had a wider reliability interval and lower correlation than the parameter tested.

It was concluded that the use of computer software for cephalometric analysis done in scanned images does not increase the measurement errors when compared with hand tracing[36].

C.Szuhanek et al[37] various types of computerized analytic software are useful in analysis and measurement and they are very useful in diagnosis and treatment planning.

Dustin Roden-Johnson[38] investigated the variation of landmark identification between film and digital cephalometric tracing and compared the ability of Quick Ceph 2000 to measure the linear and angular measurement with the hand tracing method and compared the quick Ceph 2000 superimposition to the hand traced method of super imposition. It was found that there was no difference in cephalometric land mark identification made manually and digitally.

Erkan Celik et al[42] evaluated the accuracy and reliability of angular and linear cephalometric measurements using computerized method with conventional hand tracing method. The digital cephalometric system used was the Vistadent 2.1 and Jiffy Orthodontics Evaluation software program.

The result was that most of the variables showed consistency between the three methods except for nasolabial angle, ANS – Me, APFH, N perpendicular – Pg, Go – Me, and U1 – NA measurements. It also indicated that most of the cephalometric measurement were highly reproducible with direct digital radiographs using Vistadent as well as with print outs using both JOE and hand tracing[20].

H.E.M Duarte et al[43] evaluated the influence of JPEG quality factors 100, 80 & 60 on reproducibility of identification of cephalometric landmarks on lateral cephalograms compare with digital imaging. The inference was that the images of lateral cephalograms with quality factors 100, 80 & 60 did not show any alteration in the reproducibility of identification of landmarks when compare with the DICOM format.

T Sommer et al[45] evaluated the precision of the cephalometric analysis using orthodontic software Orthometric[45] in two mode: in fully automatic mode without any help by the user and semiautomatic with manual determination of all cephalometric landmarks. It was concluded that the fully automatic determination of the cephalometric landmarks has led to relevant erros , so its mandatory to check all automatically set landmarks and should be corrected if necessary.

Julia Naoumova et al[46] compared the accuracy of cephalometric measurement made with digital tracing software FACAD with equilvalent hand traced measurement. From his study it was concluded that the results of two investigated tracing methods are similar and the computerized digital software FACAD is reliable and can be used routinely.

Omur Polat-Ozsoy et al[47] compared the digital tracing with conventional hand tracing method. He compared pre-treatment and post-treatment lateral cephalogram. Analysis was done using computerized software Vistadent and was compared with manual tracing. Significant difference was found between the two methods for SNA, Wits Appraisal, FMA, SN – PP, U1 – FH, L1 – NB.

No significant difference were found between the two method in the measurement of treatment changes.

Tancan Uysal et al [48] evaluated intra-examiner repeatability and inter-examiner reproducibility of landmarks using two cepholometric analyzing techniques. 11 angular and 6 linear parameters were traced and measured by two examiners using manual method and Dolphin image software. It was found that both operators were generally consistent in repeated measurements. For one examiner the difference for Na $\perp$ A ($p < 0.001$), Na $\perp$ Pog and U1 – Na ($p < 0.01$) distance measured were found to be statistically significant. Intra-examiner repeatability of land marks both with Dolphin and manual technique showed high correlation coefficient. While the inter-examiner reproducibility of landmark was unacceptable, measurement errors with the manual technique were generally comparable with the Dolphin technique.

Thurzo A et al[49] compared the manual and digital cephalometric analyses and came to the conclusion that the validity and reproducibility of analyses carried out manually and digitally is in high mutual correlation and therefore the software analysis can be fully substitute the manual method.

Priscila De Araujo Guedes et al[50] conducted a comparative analysis between the manual and computerized tracing using specific software in order to define inter and intra observer results. He obtained both angular and linear measurements . From his study he concluded that confidence can be increased in tracing obtained form computer-assisted cephalometric analysis, as the discrepancies found between inter and intra observer tracing , both manual and computerized were mostly statistically significant.

Georgios Tsorovas et al[51] compared hand tracing and computerized cephalometric analysis program with and without advanced features to find out the accuracy and time demands. Out of the 23 measurement he tested for each procedure L1 to NB showed better agreement with hand tracing , when the advanced features were used 20 showed good agreement with hand tracing foe both basic and advanced features. Two measurements showed poor intra – user reproducibility. The hand tracing took a significantly longer time for both basic and advanced features.

Janalt Damstra et al[52] determined the reliability and the measuring error of 11 angular and 14 linear measurement commonly used for cephalometric analysis. Twenty five digital lateral cephalograms were randomly selected and traced with Viwbox software. It was repeated 3 times by 2 observers during 3 sessions. It was observed that intraobserver agreement of the measurements was good. SNA, SNB, ANS, and ANS – Me had the smallest intraobserver errors for both observers. Except for SN – FH interobserver agreement was good. It was concluded that the appropriate measuring errors of cephalmetric measurements by maen of the smallest detectable difference is necessary to find the true difference between the start and end of active treatment. Depending on the magnitude of clinical significance, the measuring error was possibly clinically significant for all variables tested and therefore quesstons the use of these variables to detect the true treatment effects.

Huseyin Olmez et al[53] compared the difference between manual and cephalometric measurements on different sections on human skull, which were obtained using computer assisted three-dimensional analysis and conventional two-dimensional techniques. Measurements were carried out on 13 dry human skull, then 2D cephalograms and 3D images were obtained. Anatomical landmarks were determined and marked with clay before CT images were taken and those same land marks where marked with metallic balls and pins for lateral and frontal cephalograms. The measurements were measured manually and by 3D cephalometric measurements were taken. Form the study it was concluded that all measurements were statistically insignificant between the computer assisted 3D and manual measurements. On the other hand the difference between the conventional 2D and the manual measurement were statistically significant. The greatest amount of magnification was found at the Nasion – Menton distance which was located at the farthest distance form the central X-ray beam in the lateral cephalogram.

Mustafa Erkan et al[54] compared the traditional method of manual cephalometirc tracing with four different computerized tracing program. The four computerized tracing program used are Dolphin Imaging, Vistadent, Nemoceph and Quick Ceph. It was found that no statistically significant difference was found between manual tracing and the computerized tracing program. The measurements obtained with the cephalometric analysis program used in the study were reliable.

Juliane Marcela Guimaraes da Silva et al[55] compared conventional lateral cephalogram with the digital one. Ricketts cephalometric analysis was performed on both convention and digital radiographs. After statistical analysis, it was found that there was no significant difference between digital radiographs and conventional radiographs. There was high correlation between the techniques.

Kenan Cavdar et al[56] Compared conventional cephalometric analysis with Jiffy Orthodonitc Evaluation and Quick Ceph Image Pro computerized cephalometric program and investigated the reliability of computerized cephlometric methods. His study showed a high level of reliability in 88% of the evaluated variables. The Anterior cranial length and corpus length was found to have a low level of reliability. It was concluded that computerized analysis is reliable and advantageous with respect to time, archiving and enhancement of radiographs.

Parmjit Singh et al[57] compared the conventional hand tracing manual method with a picture archiving and communication system. The aim of the study was to evaluate the cephalometric measurement made on the screen using PACS compared with the conventional hand tracing method. Six angular and four linear parameters were measured. He concluded that for electronic method SNB and lower incisor angle were the only parameters found to be significantly different between the two operators for hand tracing method. All the measurements were comparable between the two methods. This study would suggest that using PACS may be an acceptable method for obtaining cephalometric measurement for treatment planning.

S.F.AlBarakati et al[58] assessed the reliability and reproducibility of angular and linear measurement of conventional and digital cephalometric methods. In this study a total of 13 landmarks and 16 skeletal and dental parameters were defined and measured on pre – treatment cephalometric radiographs of 30patients. This was performed twice by the same examiner in a time interval of 6 weeks. The reproducibility of the methods were calculated. It was found that in both the methods of conventional and digital cephalometric analysis are highly reliable. Although the reproducibility of the two methods showed some statistically significant difference , difference were not clinically significant.

Materials & Methods

The aim of this present study was to compare the accuracy and reliability of three different computerized cephalometric analytic program keeping the conventional manual tracing method as standardized, as well as to evaluate inter observer values.

The study was conducted on pre-treatment lateral cephalograms of 20 patients. No differentiation was made for age or gender. Only good quality radiographs without any artifacts were selected.

All the 20 Lateral Cephalograms which were selected were taken from the same cephalostat. The distance between the mid sagittal plane of patient head and the X-ray source in the cephalometric unit was maintained at 5 feet. The size of the film used was 8 X 10 inches. All subjects had been positioned in the cephalostat with the sagittal plane at right angles to the path of the X-rays, the Frankfort plane parallel to the floor. The occlusion was established in centric occlusion.

THE CRITERIA'S FOR SELECTION OF LATERAL CEPHALOGRAM

- Full complement of teeth upto second molar should be essentially present.
- Absence of any periapical pathologies.
- The radiographs should be devoid of any artifacts .
- The dentition should be in centric occlusion and the lips should be in a relaxed position
- No craniofacial deformity or asymmetry.
- There should not be any excess soft tissue that could potentially interfere with location of anatomical points.

CEPHALOSTAT :

The cephalostat used was Gendex DX GP 700™ provided by Gendex, Pennsylvania. The distance between the patients head and the x-ray source in cephalometric unit is 5 feet. The exposure parameters of the lateral cephalogram was fixed at 90KVp, 13mA, for a period of 12 seconds.

ARMAMENTARIUM USED

I. MANUAL TRACING

a. Acetate tracing sheet of 0.003 inch thickness
b. 0.5 mm lead pencil (HB)
c. Illuminated viewing screen
d. Tracing table
e. Measuring devices – ruler, sets square, protractor.

METHOD OF CONVENTIONAL HAND TRACING

Conventional hand tracing was performed in a darkened room using an illuminated viewing screen. The x-ray was secured to the surface of the viewing box and a sheet of fine transparent acetate paper of 0.003 inches was taped over the x ray.

Tracing was carried out using 0.5 mm HB lead pencil, landmarks were identified by a single point, in a predetermined order. For bilateral structures and double images the mid-point was chosen by construction. After landmark identification linear and angular measurements (tracing) were made. The values obtained from manual tracing were considered as the control group for the study.

II. DIGITAL TRACING

The following three digital computerized tracing software were used

a) NemoCeph

b) Facad

c) Onyx

a) NEMOCEPH NX 2006 (Nemotec, Madrid, Spain)

Configuration of the system used:

OPERATING SYSTEM	-	Windows 7
PROCESSOR	-	Intel core i3 processor
RAM	-	2 GB

b) FACAD VERSION 3.3.1

Configuration of the system used:

OPERATING SYSTEM	-	Windows 7
PROCESSOR	-	Intel pentium 4 processor
RAM	-	2 GB

c) ONYX™ (Onyx Ceph® Version 2.6.24)

Configuration of the system used:

OPERATING SYSTEM	-	Windows 7
PROCESSOR	-	Intel® core™ i5
RAM	-	6 GB

All the digital images were directly imported into software programs, which automatically generates measurements after digitizing a set of landmarks.

All the images were calibrated by digitizing two points on the ruler which is inbuilt in the cephalostat.

Once the digital images were directly imported into the software programs the landmarks were located using the cross-hair tool available with each softwares, with the help of the mouse.

During the identification of landmarks on to the digital image enhancement functions like magnification, brightness and contrast were used. 40 landmarks were used to measure 5 linear and 9 angular measurements. After digitization, the values were saved. The data obtained was subjected to statistical analysis.

CONSTITUTION OF TEST GROUP:

In the present study, the samples were categorized into four groups:

Group I - Comprise of the mean values of hand tracing performed by examiner I and examiner II.

Group II - Tracing performed using computerized software Facad

Group III - Tracing performed using computerized software Nemoceph.

Group IV - Tracing performed using computerized software Onyx.

Groups	**Tracing**
Group-I	Hand Tracing (Mean of Examiner 1 & 2)
Group-II	FACAD Software
Group-III	NEMO CEPH Software
Group-IV	ONYX Software

PARAMETERS USED IN THE STUDY :

The aim of this present study was to evaluate and compare the accuracy and reliability of three different computerized cephalometric analytic program keeping the conventional hand tracing method as standardized, as well as to evaluate the inter observer variation.

For evaluating this 9 angular measurements and 5 linear measurements were considered.

THE CEPHALOMETRIC LANDMARKS USED IN THIS STUDY:

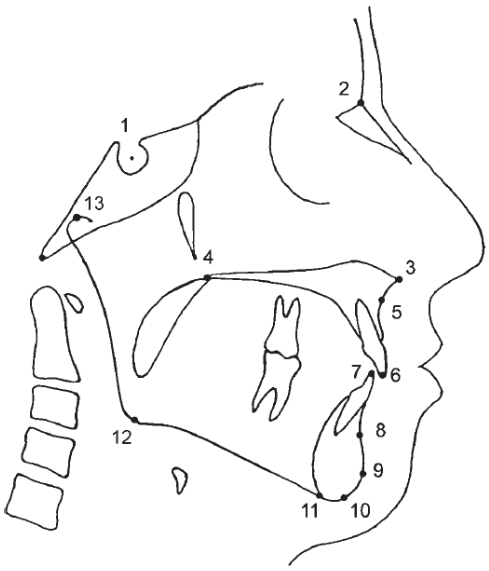


Figure 7. Cephalometric landmarks used in this study, 1 – Sella (S), 2 – Nasion (N), 3 – Anterior nasal spine (ANS), 4 – Posterior nasal spine (PNS), 5 – Point A, 6 – Incisor superius (Is), 7 – Incisor inferius (Ii), 8 – Point B, 9 –

Pogonion (Pg), 10 – Gnathion (Gn), 11 – Menton (Me), 12 – Gonion (Go), 13 – Condylion (Co), 14 – Articulare (Ar), 15 – Porion (po), 16 – Orbitale (Or), 17 – Upper incisor axis (UI), 18 – Lower incisor axis (LI)

<u>Planes Used In the Study:</u>

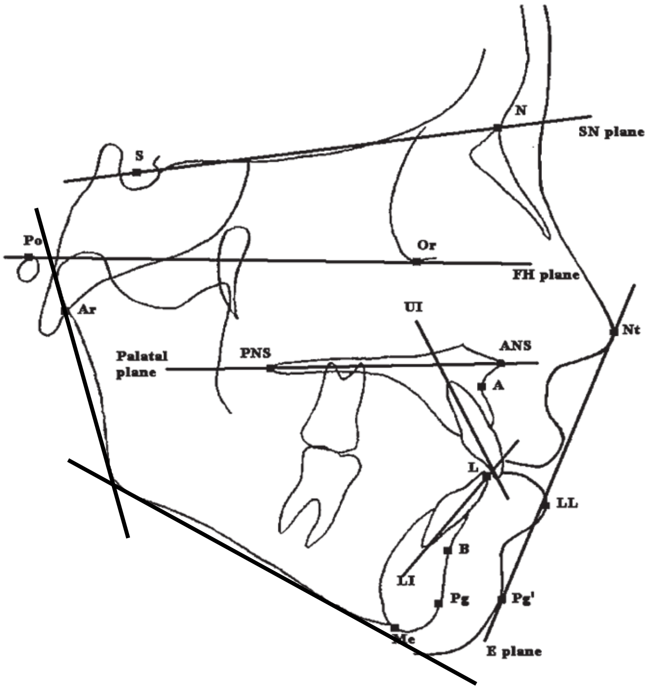


Figure 8: ANS, Anterior nasal spine; Co, condylion; Gn, gnathion; Go, gonion; LAFH, lower anterior facial height; Me, menton; MP, mandibular plane; N, nasion; PNS, posterior nasal spine; PP, palatal plane; S, Sella

Table - 10

ANGULAR MEASUREMENTS	
SNA	Anteroposterior position of the maxilla relative to the anterior cranial base
SNB	Anteroposterior position of the mandible relative to the anterior cranial base
ANB	The difference between SNA and SNB angles and defines the mutual
SN – MP	The angle formed between the SN plane and the mandibular plane
SN – PP	The angle formed between the SN plane and the palatal plane
PP – MP	The angle formed between the palatal plane and the mandibular plane
Gonial Angle	The angle between mandibular plane and ramal plane
Upper Incisor to SN	The angle formed between the long axis of upper central incisor and the anterior cranial base
Lower incisor to mandibular plane	The angle formed between long axis of lower central incisor and the mandibular plane

Table - 11

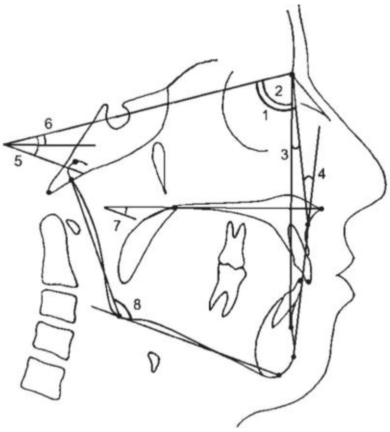
LINEAR MEASUREMENTS	
Anterior Cranial Base (N – S)	The linear distance from sella turcica and anterior point of the frontonasal suture
Mandibular Body Length (Go – Gn)	Linear distance from gonion and gnathion
LAFH	The lower anterior facial height, linear distance from ANS to menton
Upper incisor to NA	Linear measurement form the labial aspect of upper incisor to NA
Lower incisor to NB	Linear measurement form the labial aspect of lower incisor to NB

PICTORIAL REPRESENTS THE ANGULAR MEASUREMENTS :

a) Skeletal Angular Measurements: 1: SNA, 2: SNB, 3: ANB, 5: SN-Mandibular Plane, 6: SN-Palatal Plane, 7: PP-MP, 8: Gonial Angle.

b) Dental Angular Measurements: 1: U1 – SN, 2: L1 – MP

c) Linear Measurements: 1: S – N, 2: mandibular body length (Go – Gn), 3: LAFH, 4: U1 – NA, 5: L1 – NB



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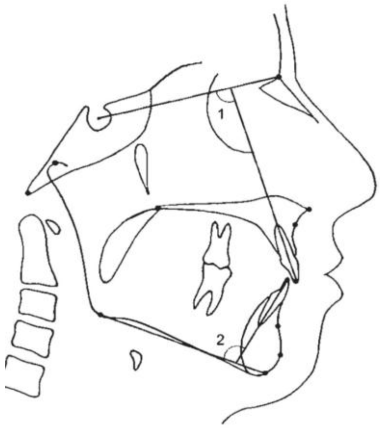
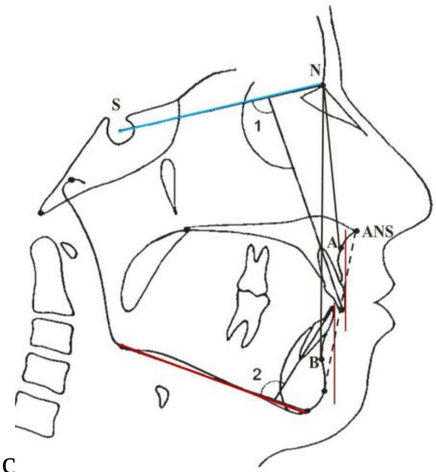


b



c

MANUAL TRACING

Manual tracing was carried in a darkened room using an illuminated viewing screen. The x-ray was firmly secured to the surface of the viewing box and a sheet of fine transparent acetate paper of 0.003 inches was taped over the x ray.

Tracing was carried out using 0.5 mm HB lead pencil, landmarks were identified by a single point, in a predetermined order. For bilateral structures and double images the mid-point was chosen by construction. After point identification linear and angular measurements (tracing) were made.

Hand tracing was carried out and the by two different examiners to evaluate inter observer results. Then the linear and angular measurements were evaluated.

ELIMINATION OF INTER EXAMINER VARIATIONS:

In this study the values of hand tracing was considered as the control group. The 20 lateral cephalograms were manually traced by two examiners to prevent the inter examiner error. The data was analysed using students " t " test for inter group comparisons. The mean value of the two examiners were taken and was considered as the value for control group.

COMPUTERIZED DIGITAL TRACING:

All the images were directly imported to the software. The images were calibrated by using the ruler built in with in the cephalostat. Once the digital images were imported to the software the cephalometric landmarks were located using the cross-hair tool available with each softwares, with the help of the mouse.

During the process of identification of the landmarks digital image enhancing functions like magnification, brightness and contrast were used. Once the landmarks were marked the software analysed the tracing and the values for nine angular and 5 linear measurements were generated. This was done for 20 x-rays with three analytical software namely Nemo Ceph, Facad and Onyx.

To evaluate the intra examiner error, the landmarks of six digital lateral cephalogram were traced by six operator using each software. The data was analysed by students " t " test for intergroup comparison.

ELIMINATION OF ERROR (FOR COMPUTERIZED DIGITAL TRACING):

In order to eliminate the interexaminer error for computerized digital tracing, identification of landmarks was done on the digital image for six x-rays by six persons. The inter examiner error was considered, and statistical evaluation was done. It was found that there was no significant difference for the mean values for the six examiners. Therefore, for the remaining fourteen x-rays, the identification of the landmarks was done by a single operator.

Results

RESULTS

The present study involved the evaluation and comparison of the accuracy and reliability of three different computerized cephalometric analytic program keeping the conventional hand tracing method as standardized, as well as to evaluate the interobserver variation. For evaluating this 9 angular measurements and 5 linear measurements were considered.

In the present study, the samples were categorized into four groups:

Group I - Comprise of the mean values of hand tracing performed by examiner I and examiner II.

Group II - Tracing performed using computerized software Facad

Group III - Tracing performed using computerized software Nemoceph.

Group IV - Tracing performed using computerized software Onyx.

The data was analyzed using SPSS (16.0) version. Student "t" test was used to find significant difference between the groups. ANOVA was used for statistical analysis. Post Hoc test, followed by Dunnet's test was used for multiple comparisons. $P < 0.05$ between groups was considered statistically significant at 95% of confidence interval.

The accuracy and reliability of inter group comparison (done by examiner I & examiner II) for manual tracing was statistically analyzed using student ' t ' test.

Table 1, indicates the comparison of linear measurements of examiner I and examiner II, the P value is > 0.05 which shows there is no statistically significant difference between examiner I and examiner II and the mean value of the two examiners were calculated. This is represented in graph I.

Table 2, shows the comparison of linear measurements of six examiners using the computerized software Facad. There is no statistically significant difference between the six examiners as the $P > 0.05$ and their mean value was compared. This is represented in Graph 2 .

Table 3, shows the comparison of linear measurements of six examiners using the computerized software Nemoceph. There is no statistically significant difference between the six examiners as the $P > 0.05$ and their mean value was compared. This is represented in Graph 3.

Table 4, shows the comparison of linear measurements of six examiners using the computerized software Onyx. There is no statistically significant difference between the six examiners as the $P > 0.05$ and their mean value was compared. This is represented in Graph 4.

Table 5, explains multiple comparison of linear measurements of different groups. In this groups comparison the P value for all the groups was >0.05, its considered there is no significant difference between the groups. Here there was a numerical difference between the groups but it is not statistically significant difference. This is shown in Graph 5.

Table 6 & 7, indicates the comparison of angular measurements between two different examiners, it was observed that the P value is > 0.05 which shows there is no statistically significant difference. This is represented in graph 6 & 7.

Graph 8 & 9, shows the mean values of angular measurements of six examiners using the computerized software Facad. When the mean values are computed there was no statistically significant difference between the six examiners.

Graph 10 & 11, shows the measured mean values of angular measurements of six examiners using the computerized software Nemoceph.

There was no statistically significant difference between the six examiners when the P value was calculated.

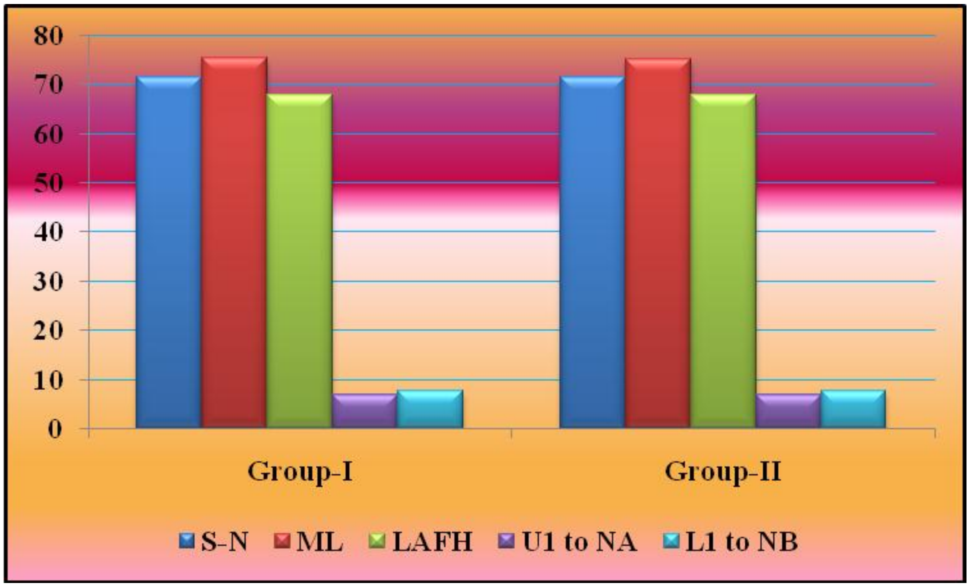
Graph 12 & 13, shows the mean values of angular measurements of six examiners using the computerized software Onyx. When the mean values are computed there was no statistically significant difference between the six examiners.

Table 8 & 9, shows the multiple comparison between manual tracing with three different computerized analytic programs, the mean values of all the groups were analysed statistically, it was observed there was no statistical difference between the groups. The P values of between the group comparison given more than 0.05 which was considered statistically insignificant at 95% confidence interval. Which is represented in graph 14 & 15.

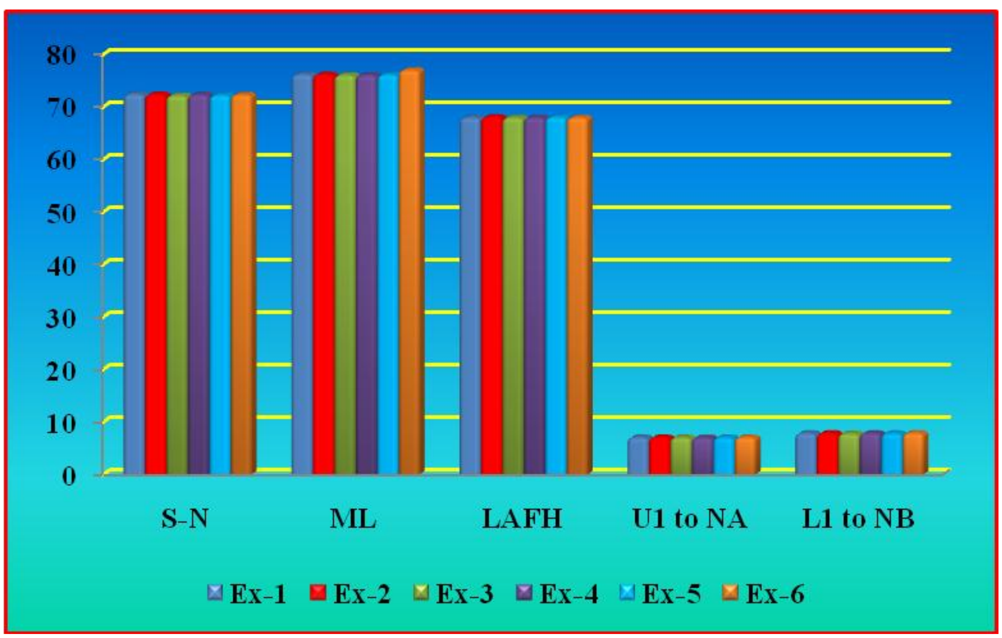
In this study, the mean values of angular and linear measurements of the manual tracing was compared with the three different computerized softwares. When comparing the accuracy and reliability angular and linear measurements with the three different computerized softwares NemoCeph gave the most accurate and reliable results, which was followed by Facad and Onyx.

Graphs

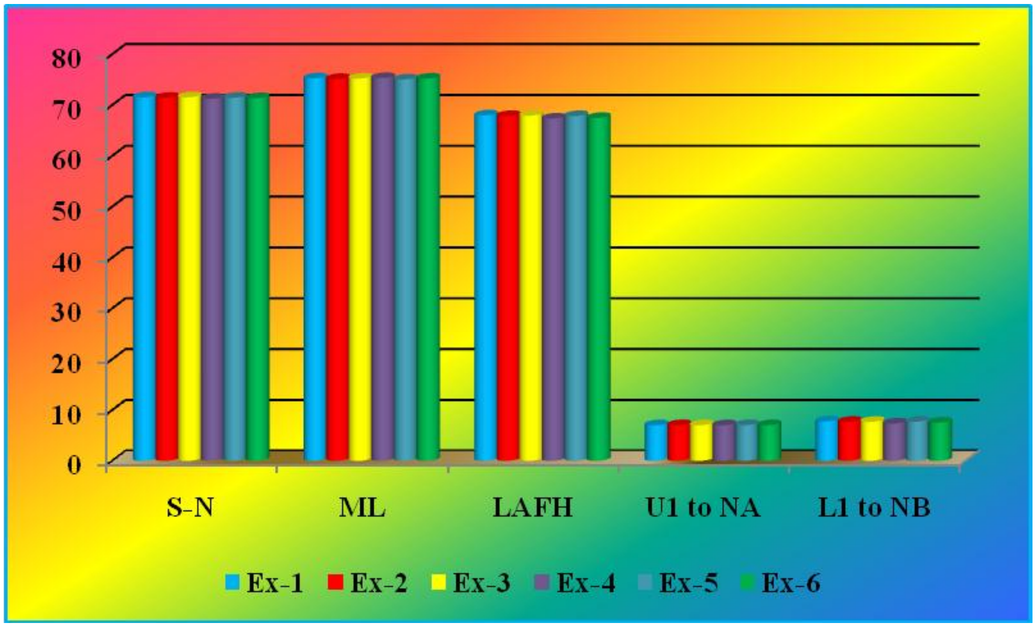
Graph-1: Mean values of linear measurements (mm) of different groups



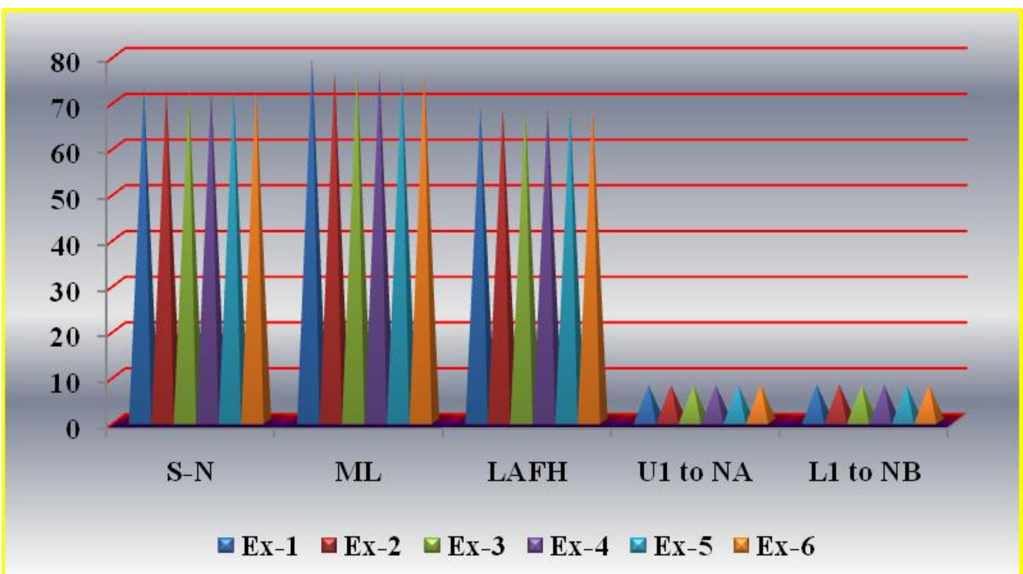
Graph-2: Mean values of linear measurements of different examiners using FACAD software



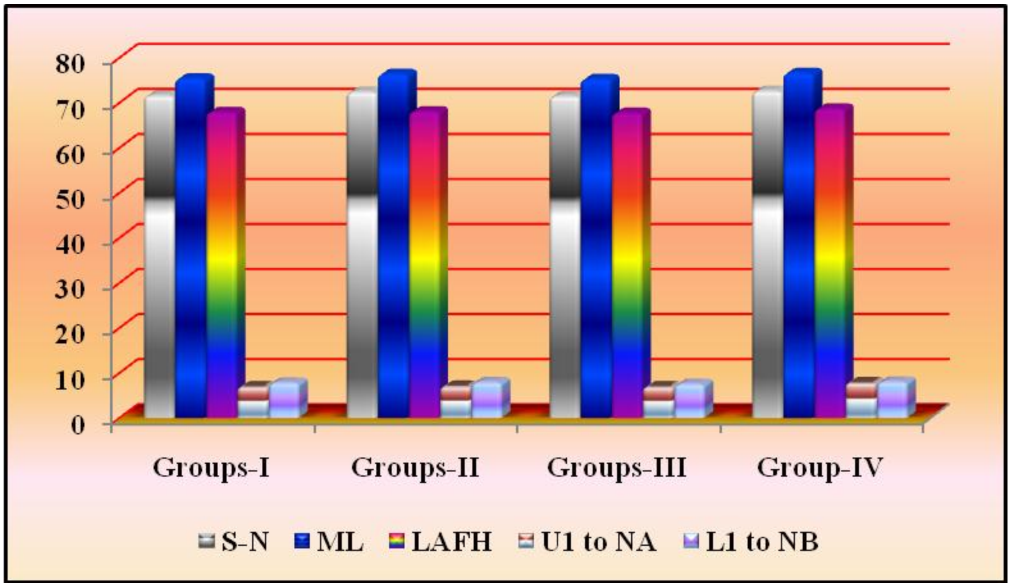
Graph-3: Mean values of linear measurements of different examiners using NEMO CEPH software



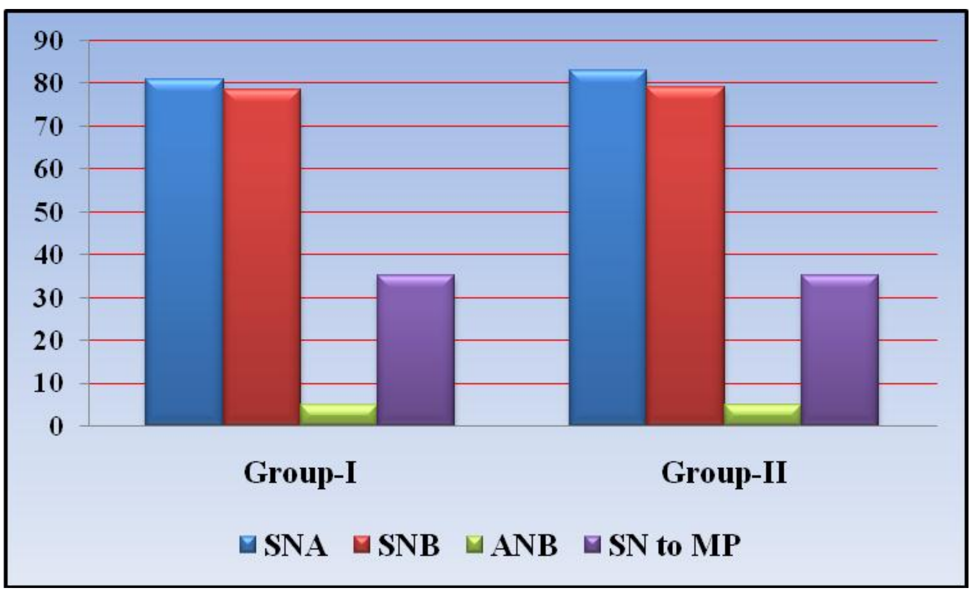
Graph-4: Mean values of linear measurements of different examiners using ONYX software



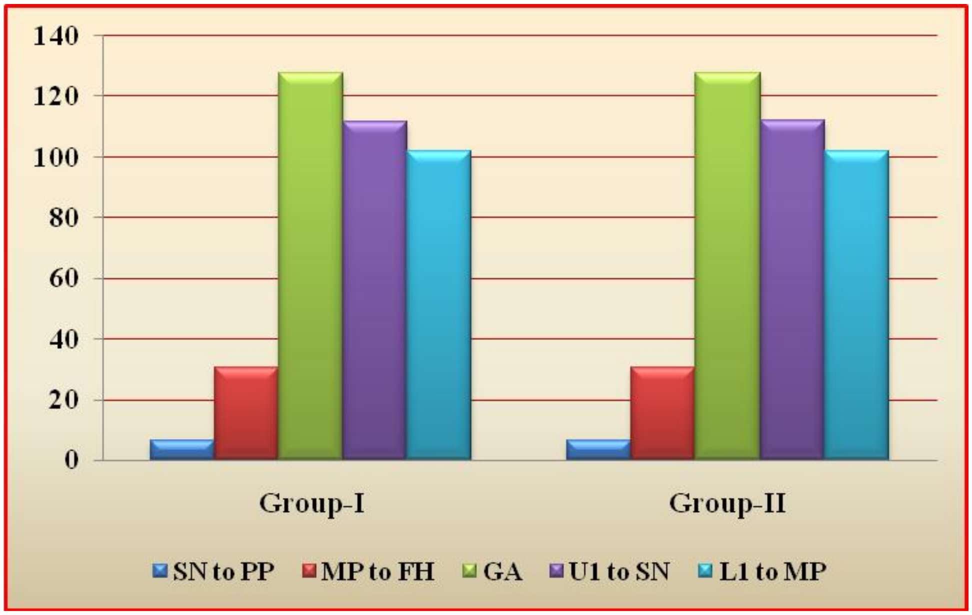
Graph-5: Multiple comparisons of mean values of linear measurements of different groups



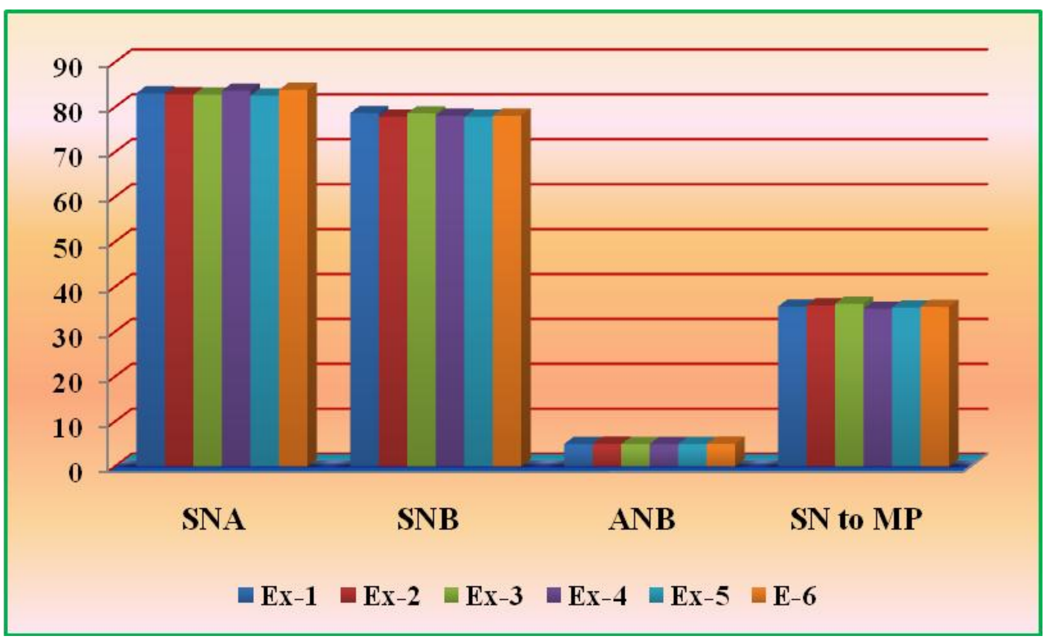
Graph-6: Mean values of angular measurements of two different examiners



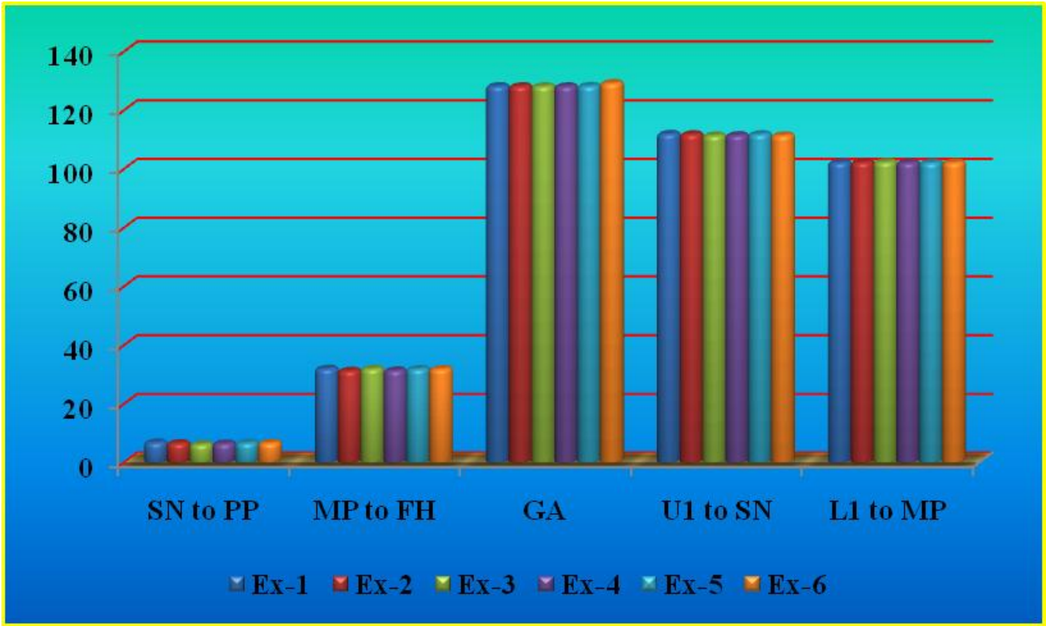
Graph-7: Mean values of angular measurements of two different examiners



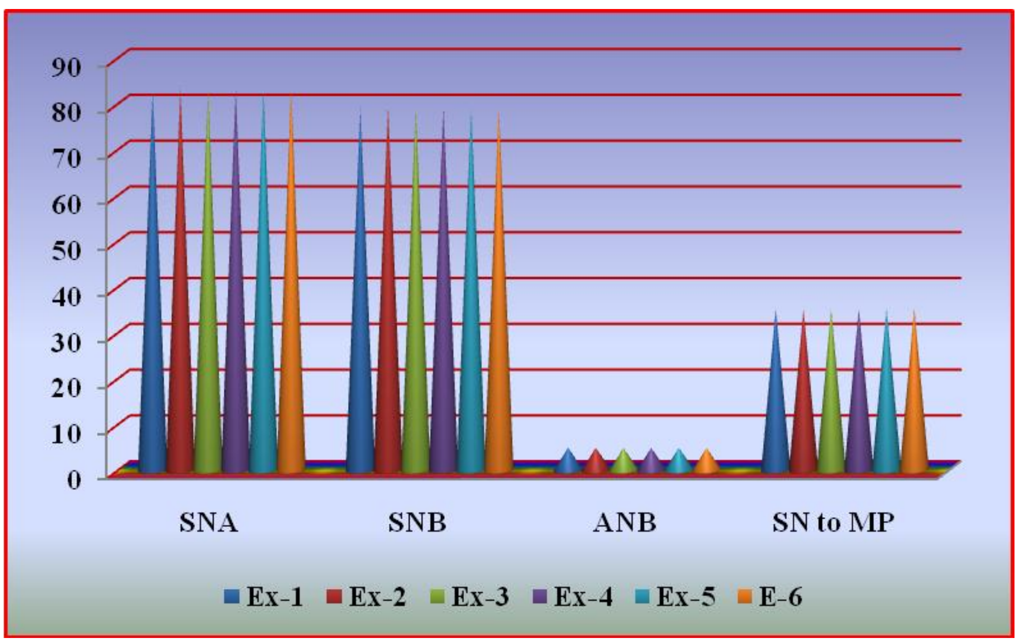
Graph-8: Mean values of angular measurements of different examiners using FACAD software



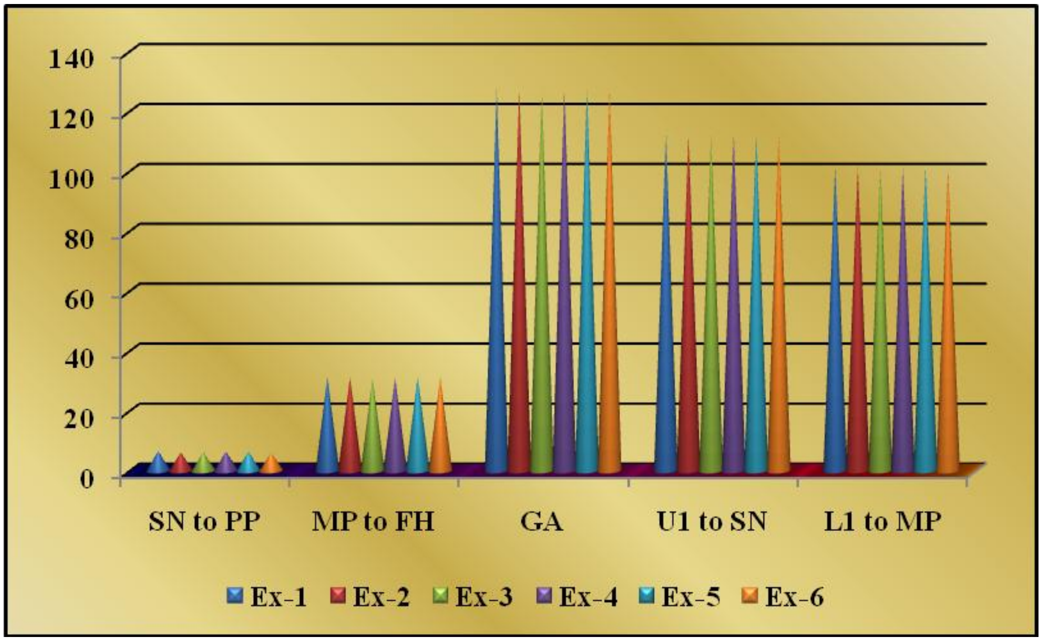
Graph-9: Mean values of angular measurements of different examiners using FACAD software



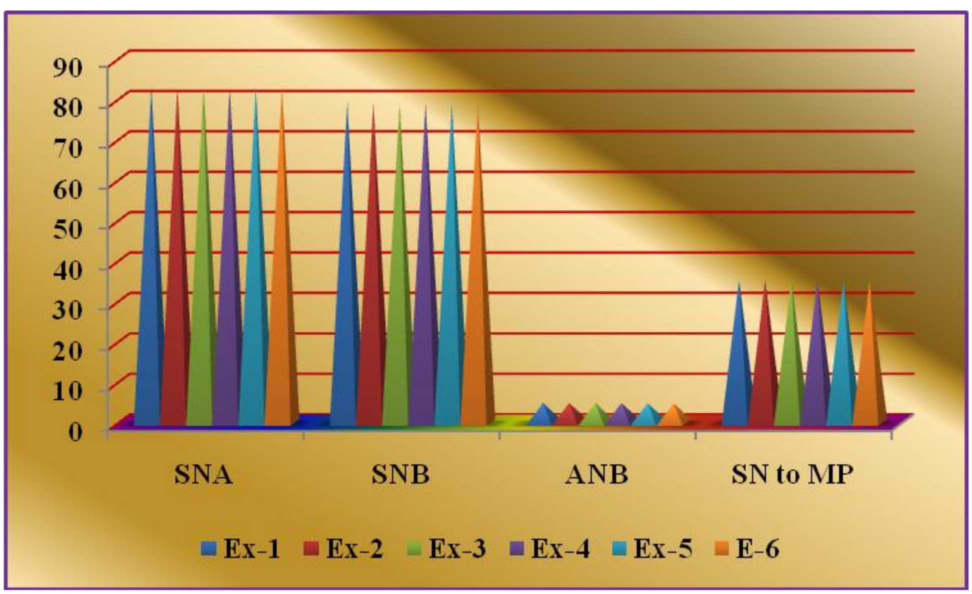
Graph-10: Mean values of angular measurements of different examiners using NEMO CEPH software



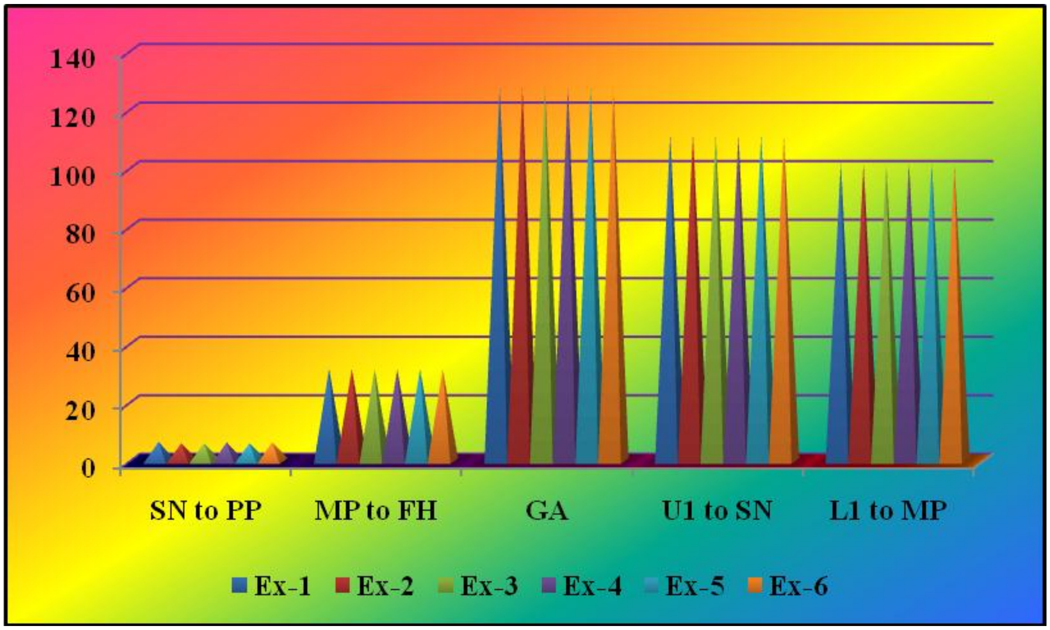
Graph-11: Mean values of angular measurements of different examiners using NEMO CEPH software



Graph-12: Mean values of angular measurements of different examiners using ONYX software

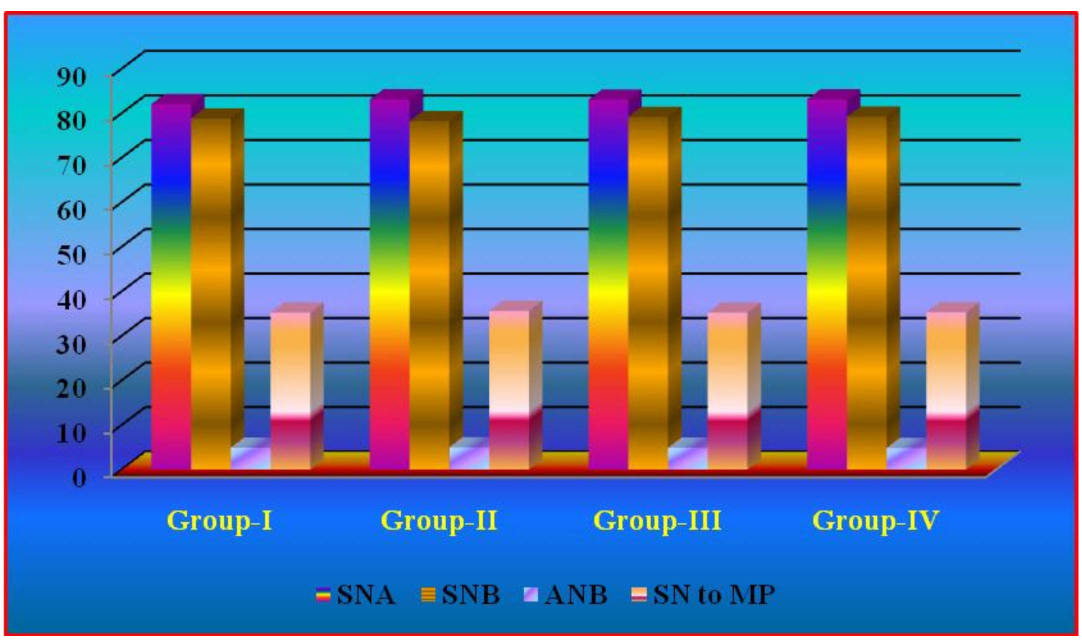


Graph-13: Mean values of angular measurements of different examiners using ONYX software

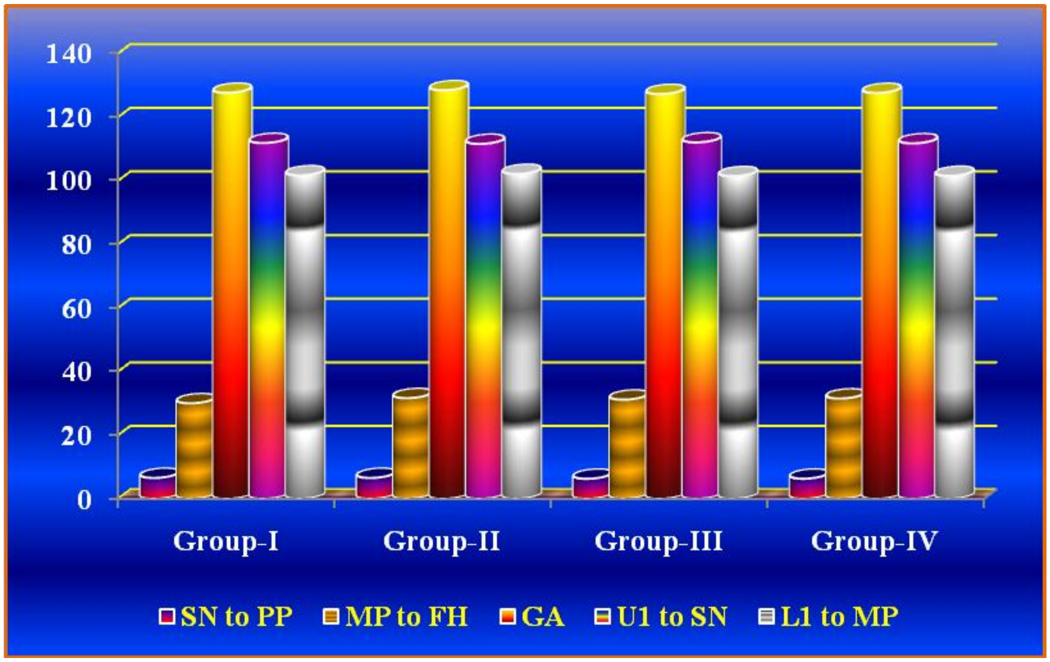


(No significant difference compared between the examiners)

Graph-14: Multiple comparison of mean values of angular measurements of different groups



Graph-15: Multiple comparisons of mean values of angular measurements of different groups



Tables

Table-1: Mean values of linear measurements (mm) of different groups

Groups	S-N Length (MEAN±SD)	Mandibular Length (MEAN±SD)	LAFH (MEAN±SD)	U1 to NA (MEAN±SD)	L1 to NB (MEAN±SD)
Group-I	71.60±3.95	75.40±4.80	67.85±5.34	7.05±1.96	7.85±2.74
Group-II	71.50±4.08	75.25±4.83	67.95±5.49	7.00±2.10	7.75±2.34
Total	71.55±3.67	75.33±4.97	67.90±5.12	7.03±1.89	7.80±2.18

Table-2: Mean values of linear measurements of different examiners using FACAD software

Groups	S-N Length (MEAN±SD)	Mandibular Length (MEAN±SD)	LAFH (MEAN±SD)	U1 to NA (MEAN±SD)	L1 to NB (MEAN±SD)
Examiner-I	72.50±3.96	76.25±4.62	68.05±5.54	7.12±2.01	7.90±2.55
Examiner-II	72.43±3.18	76.20±4.19	68.12±5.18	7.10±2.10	7.92±2.19
Examiner-III	72.23±3.20	76.13±4.18	68.03±5.03	7.11±2.03	7.84±2.45
Examiner-IV	72.37±3.89	76.12±4.18	68.03±5.17	7.09±2.00	7.93±2.46
Examiner-V	72.28±3.73	76.20±4.18	68.12±5.19	7.10±2.02	7.89±2.38
Examiner-VI	72.38±3.82	77.09±4.65	68.03±5.10	7.11±2.03	7.94±2.89
Total (MEAN±SD)	72.37±3.12	76.33±4.34	68.06±5.35	7.11±2.04	7.90±2.18

Table-3: Mean values of linear measurements of different examiners using NEMO CEPH software

Groups	S-N Length (MEAN±SD)	Mandibular Length (MEAN±SD)	LAFH (MEAN±SD)	U1 to NA (MEAN±SD)	L1 to NB (MEAN±SD)
Examiner-I	71.50±4.08	75.25±4.83	67.95±5.49	7.00±2.10	7.75±2.33
Examiner-II	71.42±4.94	75.12±4.56	67.84±5.38	7.03±2.19	7.68±2.89
Examiner-III	71.52±4.19	75.20±4.19	67.90±5.32	7.00±1.04	7.67±2.10
Examiner-IV	71.23±4.00	75.31±4.89	67.34±5.23	6.99±2.95	7.34±2.01
Examiner-V	71.43±4.92	75.03±4.12	67.83±5.23	7.03±2.56	7.70±1.94
Examiner-VI	71.34±4.04	75.20±3.97	67.46±5.10	7.02±2.19	7.53±2.19
Total (MEAN±SD)	71.41±4.89	75.19±4.05	67.72±5.18	7.01±2.78	7.51±2.05

Table-4: Mean values of linear measurements of different examiners using ONYX software

Groups	S-N Length (MEAN±SD)	Mandibular Length (MEAN±SD)	LAFH (MEAN±SD)	U1 to NA (MEAN±SD)	L1 to NB (MEAN±SD)
Examiner-I	72.90±3.95	76.70±4.79	68.89±5.13	7.93±2.26	8.05±2.58
Examiner-II	72.78±3.19	76.56±4.23	68.70±5.10	7.94±2.57	8.03±2.78
Examiner-III	72.36±3.23	76.67±4.53	68.63±5.17	7.90±2.18	8.01±2.01
Examiner-IV	72.34±4.03	76.72±4.89	68.56±5.10	7.92±2.01	8.00±2.00
Examiner-V	72.34±4.01	75.99±4.27	68.59±5.34	7.93±2.04	7.99±2.13
Examiner-VI	72.84±3.18	76.63±4.89	68.56±5.23	7.99±2.23	8.03±2.78
Total (MEAN±SD)	72.59±3.78	76.55±4.67	68.66±5.09	7.94±2.18	8.02±2.45

Table-5: Multiple comparisons of mean values of linear measurements of different groups

Groups	S-N Length (MEAN±SD)	Mandibular Length (MEAN±SD)	LAFH (MEAN±SD)	U1 to NA (MEAN±SD)	L1 to NB (MEAN±SD)
Group-I	71.55±3.67	75.33±4.97	67.90±5.12	7.03±1.89	7.80±2.18
Group-II	72.37±3.12	76.33±4.34	68.06±5.35	7.11±2.04	7.90±2.18
Group-III	71.41±4.89	75.19±4.05	67.72±5.18	7.01±2.78	7.51±2.05
Group-IV	72.59±3.78	76.55±4.67	68.66±5.09	7.94±2.18	8.02±2.45

Table-6: Mean values of angular measurements of two different examiners

Groups	SNA (MEAN±SD)	SNB (MEAN±SD)	ANB (MEAN±SD)	SN to MP (MEAN±SD)
Groups-I (Examiner–I)	81.05±2.99	78.40±3.33	4.85±2.36	35.20±3.96
Groups-II (Examiner-II)	83.10±3.11	79.25±4.13	5.00±2.43	35.25±3.93
Total	82.08±2.56	78.83±3.86	4.92±2.18	35.23±3.67

Table-7: Mean values of angular measurements of two different examiners

Groups	SN to PP (MEAN±SD)	MP to FH (MEAN±SD)	Gonial Angle (MEAN±SD)	U1 to SN (MEAN±SD)	L1 to MP (MEAN±SD)
Group-I (Examiner-I)	6.55±2.50	30.40±4.51	127.75±6.40	111.67±9.26	101.65±8.63
Group-II (Examiner-II)	6.60±2.50	30.30±4.63	127.60±6.36	112.10±9.01	101.80±8.67
Total	6.58±2.14	30.35±4.28	127.68±6.13	111.89±9.12	101.73±8.45

Table-8 : Multiple comparison of mean values of angular measurements of different groups

Groups	SNA (MEAN±SD)	SNB (MEAN±SD)	ANB (MEAN±SD)	SN to MP (MEAN±SD)
Groups-I	82.08±2.56	78.83±3.86	4.92±2.18	35.23±3.67
Group-II	83.15±2.78	78.22±2.65	5.01±1.68	35.62±4.26
Group-III	83.08±2.67	79.19±4.08	4.88±2.56	35.25±3.43
Group-IV	83.13±2.84	79.24±4.06	4.87±2.17	35.30±3.95

Table-9: Multiple comparison of mean values of angular measurements of different groups

Groups	SN to PP (MEAN±SD)	MP to FH (MEAN±SD)	Gonial Angle (MEAN±SD)	U1 to SN (MEAN±SD)	L1 to MP (MEAN±SD)
Group-I	6.58±2.14	30.35±4.28	127.68±6.13	111.89±9.12	101.73±8.45
Group-II	6.58±2.38	31.67±4.09	128.48±6.28	111.61±9.13	102.17±8.23
Group-III	6.32±2.05	31.19±4.49	127.29±6.23	112.09±9.24	101.46±8.23
Group-IV	6.34±2.54	31.55±4.23	127.63±6.12	111.79±9.04	101.55±8.21

Figures

Discussion

DISCUSSION

Lateral cephalograms continue to be one of the orthodontic records which provide vital information about the sagittal and vertical relation of the craniofacial skeleton, soft tissue profile, dentition, airway and cervical vertebrae. The structures and their relationships to each other were scrutinized by means of linear and angular measurements as well as by the use of ratios based on the various cephalometric landmarks[1].

Conventionally, cephalometric evaluation was done manually using acetate overlays on the cephalogram and measuring the linear and angular measurement manually. This technique bore some advantages in that it was easy to follow, economical and did not need any special equipment.

The source of errors in manual tracing includes the variation in landmark identification, errors in measurement, magnification errors[2.4,6,10], reduction of three dimensional object to two dimensional object[10]. Measurement of distances and angles between landmark locations were defined by the limitations of measurement devices (ruler and protractor)[7] as well as the limitations of human visual performance in case of manual tracing as reported by Forsyth et al[17,18]. Human errors can occur both in recording of measurements or in the use of measurement devices[46]. Time required for manual analysis is more and depends on how comprehensive the measurements are, and on the operator's skill of identifying the landmarks[30].

To overcome the shortcomings of the conventional tracing technique, computerized cephalometric systems were introduced into clinical orthodontics. This technique is being used extensively for diagnosis, treatment evaluation and simulation of treatment outcomes. The process requires 10% of time of a normal manual registration because it is only necessary to digitize the radiographic points directly on the cephalogram[30] .The advantages the calculations are done within no time. This process removes human error except for errors of landmark identification. Ssu – kuang Chen et al[30] showed that computerized analysis can reduce the human errors introduced during manual measuring procedure.

There are several other benefits of digital method which include easy storage and retrieval of cephalometric values and tracings, integration of cephalometric registrations within office management computerized system, combination of cephalometric data with patient's files, photographs and dental casts. Digital imaging has been shown to offer several advantages over conventional radiography. Study by Forsyth et al[18] has outlined the advantages and limitations of digital imaging. Data processing is faster. Radiation dose is reduced by 30% and since there is no film processing, chemical and environmental risks are eliminated. Heiko Visser et al determined the radiation exposure with conventional and direct digital cephalometric radiography. Absorbed dose from conventional radiography was approximately 2 fold higher than digital radiographic unit. Exposure errors can be corrected and images can be enhanced using different techniques inorder to provide more precise landmark identification.

There are also several drawbacks present . Here it represents the two dimensional representation of a three dimensional structure, so there will be difficulty in identifying the landmarks. There will be superimposition of the bilateral structures, the resolution of the image will be affected as the image is compressed[36]. This computerized cephalometric analysis also requires digital cephalometric radiographic machine as well as its software which is expensive. Inspite of all these shortcomings

The increasing use of digital cephalometrics has highlighted the need to evaluate the accuracy of the new computerized software programs and compare them with traditional manual measurement technique. Several studies have examined the performance of commercially available software programs used for cephalometric analysis.

This study evaluated three different computerized cephalometric programs FACAD, NEMOCEPH AND ONYXCEPH. Comparisons were made between these computerized technique and hand tracing in terms of accuracy of individual measurements and time demands.

Sheldon Baumrind et al[3] reported that conventional cephalometric analysis have magnification, tracing, measuring, recording and landmark identification to be the major source of error. Most studies evaluating the accuracy of on-screen computer tracing software have transferred conventional cephalometric film to a digital format by scanning, a procedure that may result in image distortion. Bruntz et al[35] found both vertical and horizontal distortion when analogue film was converted to digital format using a scanner and he concluded that use of digital cephalometrics in orthodontic clinics are becoming more wide spread and direct transfer of images to a computer database can be done. Ralf kurt Willy et al[37] showed that effective magnification was larger for the digital images but the average difference was entirely below 1. Inorder to eliminate errors due to magnification, the present study was based on digital radiographs rather than scanned images.

Conventional measurements were taken using hard-copy printouts of the digital radiographs. Although a previous study found that slight enlargement may occur when printing hard copies of digital cephalograms, the size difference was minimal and regarded as clinically acceptable[30].

Conventional manual tracing was considered as the control group. Mustafa Erkan[54] inferred that inter-examiner error was greater than intraexaminer error. So the manual tracing was performed by two examiners, examiner 1 and examiner II. There angular and linear measurements and is represented in table 1 and table 6. There mean values where taken and was considered as the control group. The values of examiner I and examiner II didn’t show statistical significance. The data was analyzed using SPSS (16.0) version. Student “t” test was used to find significant difference between the groups. $P < 0.05$ between groups was considered statistically significant at 95% of confidence interval.

The accuracy and reliability of inter group comparison (done by examiner I & examiner II) for manual tracing was statistically analyzed using student ‘ t ‘ test.

Table 1, indicates the comparison of linear measurements of examiner I and examiner II, the P value is > 0.05 which shows there is no statistically significant difference between examiner I and examiner II and the mean value of the two examiners were calculated. This is represented in graph I.

Table 6 & 7, indicates the comparison of angular measurements between two different examiners, it was observed that the P value is > 0.05 which shows there is no statistically significant difference. This is represented in graph 6 & 7.

The accuracy of cephalometric analysis is important for treatment planning so that the clinician can correctly assess the various treatment options. Landmark identification is highly affected by operator experience, which might be as important as the tracing method itself. As the interoperator error has been found to be greater than intraoperator error, landmark identification for six lateral cephalogram on all the three computerized cephalometric software was performed by six operators.

There angular and linear measurements was analyzed using SPSS (16.0) version. ANOVA was used for statistical analysis. Post Hoc test, followed by Dunnet's test was used for multiple comparisons. $P < 0.05$ between groups was considered statistically significant at 95% of confidence interval.

The multiple group comparison of three computerized cephalometric software is analyzed using SPSS (16.0) version. ANOVA was used for statistical analysis. Post Hoc test, followed by Dunnet's test was used for multiple comparisons. $P < 0.05$ between groups was considered statistically significant at 95% of confidence interval.

The mean value of linear measurement performed by 6 different operator using Facad, Nemoceph and Onyx is given in table 2,3 and 4 and there mean is calculated.

Mean and standard deviations were estimated from the sample for each study group. ANOVA was used for statistical analysis. Post Hoc test, followed by Dunnet's test was used for multiple comparisons. $P < 0.05$ between groups was considered statistically significant at 95% of confidence interval.

The multiple comparison of the mean values (Table 5) of linear measurements of digital tracing with Facad (group II), it showed that the mandibular length and lower anterior facial height showed much variation from the control group whereas S-N length, U1 to NA, L1 to NB didn't show much variation from the hand tracing. Previous studies on conventional and computerized methods have found difficulties in locating landmarks gonion and gnathion[47].

The multiple comparison of the mean values (Table 8 & 9) of angular measurements of digital tracing with Facad (Group II), there was a higher variation in mandibular plane to FH, gonial angle, lower incisor to mandibular plane and SN to mandibular plane.. However SNA, SNB, ANB, upper incisor to SN also showed a slight deviation from the control group. Forsyth[17] showed similar result with larger difference for angular measurement SNA. This was because landmarks on poorly defined edges such as nasion and point A appeared to show large error. According to Chen et al[23] The higher variation in SN to MP, FH to MP, gonial angle can be due to difficulty in identifying Go as it's a poorly defined anatomical outline, a double image and localization away from the mid-sagittal plane.

The multiple comparison of the mean values (Table 5) of linear measurements of digital tracing with Nemoceph (Group III), the mean values were more close to the control group. The values showed that the mandibular length and lower anterior facial height showed much variation form the control group whereas S-N length, U1 to NA, L1 to NB didn't show much variation from the hand tracing. But when it was compared with Group II it was found that it was more accurate and reliable. The multiple comparison of the groups are shown in graph 5.

The multiple comparisons of the mean values (Table 8 & 9) of angular measurements of digital tracing with Nemoceph (Group III), the mean values were more close to the control group. There was a greater deviation in the mean values of SN to MP, MP to FH, Gonial angle and lower incisor to MP. But when these values are compared with the values of group II it is found that it is more reliable than the group II as these values are more close to the control group.

The multiple comparisons of the mean values (Table 8 & 9) of angular measurements of digital tracing with Onyx (Group IV), showed a greater deviation in the mean values when compared with the control group. Omur Polat et al evaluated the accuracy of cephalometric measurements using direct digital radiographs. Significant differences were observed for SNA, SNB, ANB, SN – MP, gonial angle, L1 to PM, FMA, SN-PP which showed deviation in mean values from the control group. The greatest deviation was noted for MP to FH, goinial angle, L1 to MP and SN to MP. Its because of difficulties in landmark location due to superimposition of anatomical structures. Due to image enhancement techniques available now such difficulties were not found with this study. In this study all the parameters showed a greater deviation of the mean from the control group.

The multiple comparisons of the mean values (Table 5) of linear measurements of digital tracing with Onyx (Group IV), showed a greater deviation in the mean values when compared with the control group. Significant difference was observed with a greater deviation was noted in mandibular length and lower anterior facial height. It is mainly due to the difficulty in landmarks. The deviation in mandibular length occurred due to difficulty in identifying the land marks gonion and gnathion where as the error for lower anterior facial height occurred due to difficulty in identifying the landmarks ANS and menton.

While comparing all the four groups, group II, III and IV showed deviation in the mean values when compared with the control group. When this deviation was statistically analyzed the $P > 0.05$ which showed that it was statistically insignificant.

Angular measurements gonial angle, MP-FH, SNA, gonial angle showed significant differences in the mean values but statistically it was insignificant. The reason for significant difference with gonial angle occurred as the point gonion cannot be constructed in digital tracing as done in manual tracing. Significant difference with SNA were due to difficulty in locating point A which is located on poorly defined outline.

Time taken by the manual tracing was approximately ten times greater than all the 5 digital tracing softwares. Study by Ssu-Kuang Chen et al[30] showed similar result and revealed that even an experienced clinician needed more than 25 minutes to perform entire analysis by traditional method whereas computerized method can reduce the time needed.

When multiple comparison of all the group of computerized cephalometric analytic program was done with the control group it was seen that group III Nemoceph showed least deviation from the control group followed by Facad and then Onyx.

Summary & Conclusion

The aim of the study was to evaluate and compare the accuracy and reliability of three different computerized cephalometric analytic program namely Nemoceph, Facad & Onyx. For the present study conventional hand tracing method was considered as the control group, this study also evaluates the interobserver variation. The parameters used in this study consist of 9 angular measurements and 5 linear measurements.

In the present study, the samples were categorized into four groups. G**roup I** - Comprises of the mean values of hand tracing performed by examiner I and examiner II, **Group II** – consists of values of tracing performed using computerized software Facad, **Group III** – comprises of values of tracing performed using computerized software Nemoceph and **Group IV**- contains the values of tracing performed using computerized software Onyx.

The accuracy and reliability of inter group comparison (done by examiner I & examiner II) for manual tracing was statistically analyzed using student ‘ t ‘ test. It was found that the P value is > 0.05 which shows there is no statistically significant difference between examiner I and examiner II and the mean value of the two examiners were calculated and was considered as the control group.

The mean values of angular & linear measurements of Group II, Group III, and Group IV were compared with the Group I which was considered as the control group.

Dunnet's test was used for multiple comparisons. $P < 0.05$ between groups was considered statistically significant at 95% of confidence interval. Multiple comparison was done with all the study group, and the result was P value > 0.05 which showed there is no statistically significance difference between the group.

From the study we come to the conclusion that all the three computerized analytic software can be used for the cephalometric analytic purpose as there is no statistically significance between the three groups.

While comparing the accuracy and reliability of the angular and linear measurements with the three different computerized software NemoCeph gave the most accurate and reliable result, which was followed by Facad and Onyx respectively.

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